Internet & Internet Protocol Version 6

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The connectivity of networks across the globe to communicate, transmit and receive data is Internet. Any communication network, wired or wireless that can carry two-way digital data can carry Internet Traffic. Networks are connected through different mediums viz. co-axial cable, optical fibre, Wi-Fi and the internet packets flow through these. The networks which share the same level of protocols form the internet. Internet is held together by different protocols which define its technical specifications and describe how to exchange data on network.

IPv6, or Internet Protocol version 6, is one such protocol which is a network layer standard used to communicate data across a packet-switched internetwork. After IPv4, it is the second version of the Internet Protocol to be formally adopted for general use. IPv6 is into existence and has been standardised for a number of years, but still research in going on auxiliary protocols like Telnet, FTP etc.

1.1 History of Internet

During the 1950s, the necessity of general communication between users of various computers and communications networks was recognised and this led to research into decentralized networks, queuing theory, and packet switching. In 1973, the United States Department of Defense created ARPA (Advanced Defense Projects Agency) NET whose primary concern was to protect their data and to establish a network which enables them to decentralise their communication hub by interlinking packet networks of various kinds and any loss of infrastructure during wars and destruction will not affect the whole network. This was called the ‘Internetting’ project and the system of networks which emerged from the research was known as the "Internet." The system of protocols which were developed over the course of this research is known as the TCP/IP Protocol Suite, in which the initial protocols are Transmission Control Protocol (TCP) and Internet Protocol (IP).

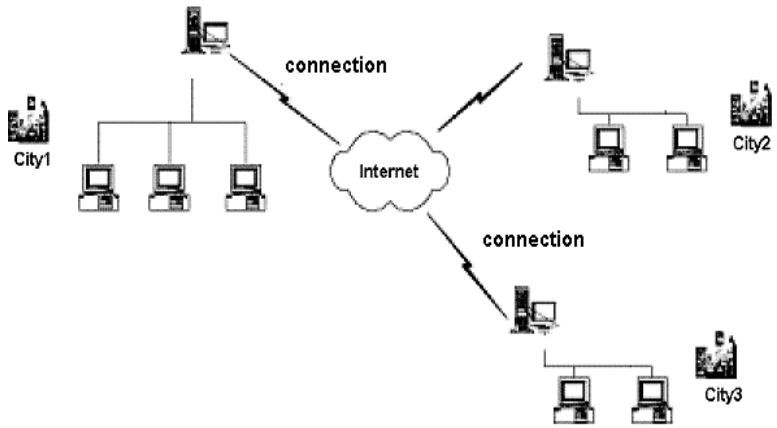

Fig 1: **Internet Connectivity between cities**
Source: http://www.datumcom.com/psavlinternet.cfm

Today the internet has pervaded into all spheres of human activity with widespread implications. The internet has almost metamorphosed many business protocols into e concepts which are flexible, productive and more time efficient.

1.2 Applications of Internet

The major applications of internet using a range of protocols often called as Internet Protocol Suite are discussed below:

1.2.1 World Wide Web

This service gives access to vast and diverse amount of online information and uses several protocols. As soon as an URL is entered in web browser it is resolved into an IP address by the global and distributed Internet database known as the Domain name system or DNS. A HTTP request is sent to the web server working at that IP address for the page required. The HTML text, graphics and any other files that form a part of the page will be requested and returned to the client in quick succession. The web browser displays the page as described by the HTML and other files received, incorporating the images, links and other resources as necessary.

1.2.2 Remote Access

Internet allows a user to connect to other computers across the world. It can be with or without the use of security, authentication and encryption technologies. A Virtual Private Network (VPN) allows a user to connect to any other computer and open a remote session. A public IP and an authentication to enter a network allow a user to remotely access a computer. PC Anywhere and VNC are some tools by which one can connect to a remote computer.

1.2.3 File- Sharing

A file can be easily shared, send or it can be received via internet. Internet uses several protocols like IMAP, POP3 which enables a user to mail and attach files to that. Other ways includes FTP, where the user can transfer or download a file from server by proper authentication. Peer to peer networking is another way to upload and download data.

1.2.4 Streaming Media and VoIP

Fig 2: **VoIP Model Diagram**
http://www.ciibis.com/voip.html

Internet can be used to access on-line media. Also web-casts, video conferencing, and online chatting are possible. Voice over Internet Protocol (also called VoIP, IP Telephony) is the routing of voice conversations over the Internet or any other IP-based network. The voice data flows over a general-purpose packet-switched network, instead of traditional dedicated, circuit-switched voice transmission lines.

Each machine is recognised on internet by a separate IP address. Every computer (host or client) and router has an IP address, which encodes its network number and host number. This combination is unique and no two machines can have the same IP address. IPv4, Internet Protocol version 4 was the first widely accepted standard worldwide for IP addressing. And most of present day internet uses IPv4 only.

2.1 Why IPv6?

In the present day world where internet users count has crossed one billion mark and various devices functioning on internet such as PDA's, mobiles etc. are growing there is a shortage of IPv4 addresses, which are needed by all new machines added to the Internet. There are too few IP addresses available for the future demand of device connectivity. IPv4 has the potential for 4.2 billion ($256^4 \approx 4.294 \times 10^9$) network hosts i.e. it has a 32 bit addressing format (written in dotted decimal notation e.g `10.2.6.10`) and it can only provide 4.2 billion unique addresses.

IPv6 fixes this problem and is intended to address the concern of IPv4 address exhaustion. IPv6 addresses this problem by supporting 65536^8 ($\approx 3.4 \times 10^{38}$) addresses. It is expected that IPv4 will be supported until at least 2015, to allow time for bugs and system errors in IPv6 to be corrected.

2.2 History of IPv6

IPv6 was adopted by the Internet Engineering Task Force (IETF) in 1994, and it was called "IP Next Generation" (IPng). The adoption of IPv6 has been slowed by the introduction of network address translation (NAT), which partially alleviates the problem of address exhaustion. But, NAT makes it difficult to use some peer-to-peer applications, such as Voice over Internet Protocol (VoIP) and online games. IPv6 currently accounts for just a few percent of the addresses in the publicly-accessible Internet, which is still dominated by IPv4 but very soon it is going to replace the IPv4.

2.3 Benefits over IPv4

IPv6 extends IPv4's theoretical limit of 4.2 billion addresses to 340 trillion, trillion, trillion. Internet devices will grow by an order of magnitude over the following years. It is estimated that available IPv4 addresses will expire sometime between 2006 and 2015. For the enterprise network, IPv6 provides improvements over IPv4— Increased security, mobility, QoS, and scalability. It will also enable to address every computing element within an organization and will facilitate uninterrupted communication between the hosts without any limitations. IPv6 also enforces geographic and regional addressing where the organizations will have specifications in the IP itself to recognize the location and to the provider to whom they are connected.

IPv6 is a revolutionary change to the network.IPv4 networks are getting faster, reliable and more secure. IPv6 will be an advancement which is better, faster, cheaper and for many more devices. Most network devices will start to support not only the full complement of IPv4 features, but IPv6 features as well. Network attached devices will be translated to IPv6 slowly, without any affecting the current supported features of IPv4. As new applications and devices demand the newer, better IPv6 capabilities, the infrastructure will be upgraded to support it IPv6 provides a bigger address space. But IPv6 has become much more than just IPv4 with a larger address field. Many of the functions provided by IPv4 will have another newer more efficient version for IPv6 or will be obsolete. Network functions like NAT (Network Address Translation), allowed everyone in the IT world to grow beyond the limitations of the existing address space, will be engineered out of existence. This topic covers the addressing formats and conventions that are used in IPv6. The following topics cover the major technical changes from IPv4.

3.1 Length

The primary change from IPv4 to IPv6 is the length of network addresses, with IPv6 addresses being 128 bits long .There will be 32 hexadecimal digits instead of decimal numbers separated by dots, there will be groups of 4 hexadecimal digits separated by a colon. Each hexadecimal digit can take 16 values resulting in a total of 16^{32} addresses.

IPv6 addresses are composed of two logical parts: a 64-bit network prefix, and a 64-bit host-addressing part, which is automatically generated from the interface MAC address. The aim for the 128-bit address space is not primarily to make sure that addresses never run out, but to ensure that routing can be handled smoothly by keeping the address space unfragmented. This is an improvement over IPv4, where a great number of discrete netblocks are often assigned to one organization.

3.2 Format

IPv6 addresses are written as eight groups of four hexadecimal digits. Until IPv6 replaces IPv4, the 32 bit address will be a part of the 128 bit address. The first 96 bits will be 0 and the remaining 32 bits will be the actual address. These are often followed by a slash and the prefix length known as CIDR range, which turns them into a range of IPv6 addresses. CIDR is a standard for interpretation of IP addresses and facilitates routing by allowing blocks of addresses to be grouped together. In the following example of IPv6 64 is the CIDR range `1980:DA02:AB25:08d3:2020:9010:69CD:7334/64`.

If a four-digit group is 0000, e.g.`1980:DA02:AB25:0000:2020:9010:69CD:7344/64` than 0000 can be omitted and the IP address and it can be shortened as `1980:DA02:AB25::2020:9010:69CD:7344/64`. Following this rule, any group of consecutive 0000 groups may be reduced to two colons, as long as there is only one double colon used in an address. The following address formats are valid and equivalent.

```
1980:DA02:0000:0000:0000:0000:2005:7002/64
1980:DA02:0000:0000:0000::2005:7002/64
1980:DA02:0:0:0:0:2005:7002/64
1980:DA02:0::0:2005:7002/64
1980:DA02::2005:7002/64
```

Some notations like `1980::1212::AB25/64` are invalid because it is not clear how many `0000` groups are on each side. Leading zeros in a group can be omitted. Thus `1980:0A02:0D12::0013/64` may be shortened to `1980:A02:D12::13/64.`

3.3 Addressing and routing

IPv6 address id a multicast address i.e. a user can send data to multiple destinations. It is not possible in IPv4 as it uses IGMP Protocol which is not present on many hosts. An IPv4 address is a unicast address i.e. the address is unique for one host and it can send data to a single hot and we cannot select multiple locations. Multicasting has been implemented in IPv6 by using ICMP protocol. But multicasting will only be possible if an address is assigned to the group. The first 8 bits in the IPv6 address tells distinguishes the addressing formats. For example, 00000000 is reserved for compatibility with IPv4, 01000000 is for unicast address and 11111111 is for multicast address.

IPv6 also improves routing. Because of hierarchical structures of addresses the routing tables will be smaller. They will be compressed and stored in an economized storage. The other main reason for efficiency is the use of multicasting.

3.4 Conversion of IPv4 addresses in IPv6 format

IPv4 addresses can be converted to IPv6 format. Since, most of the current systems on internet are having the IP addresses in IPv4 format it was necessary to find out solution to make an easy transition and convert them to IPv6.There are three methods by which it can be done:

1. Hexadecimal Conversion: In this the IPv4 address `132.151.32.254` can be written in hexadecimal format as `0x849720FE`, and is can be converted to an IPv6 address as `0000:0000:0000:0000:0000:0000:8497:20FE.`

2. Hybrid Compatible Address: The IPv4 address can also be noted with decimal numbers as a hybrid IPv4-compatible address, in which case the address becomes ::`132.151.32.254`.

3. Mapped address: In IPv4-mapped address, the last 32 bits of a standard IPv6 address may be written in decimal. `::FFFF:132.151.32.254` can be written as `::FFFF:8497:20FE.`

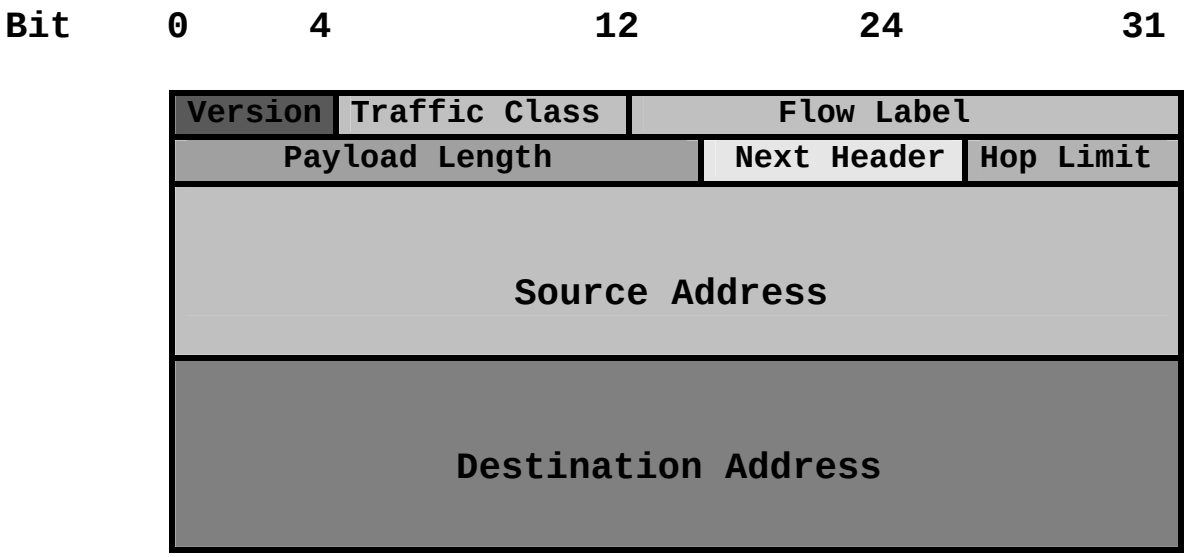

Fig 3: **The structure of an IPv6 packet header**

The IPv6 packet is composed of two main components the header and the payload. The header is in the first 40 octets of the packet and contains both source and destination addresses. After that there are extension headers. Following are the headers in order of their existence starting from IPv6 Header, Hop by Hop header, Destinations Options header, Routing Header, Fragment Header, Authentication header, Encapsulating security payload header and Destination options header.

The main fields of IPv6 header are as follows

1. **Version** – The first 4 bits are for the version number

2. **Class** – These 8 bits are for Traffic Class field which are used to provide Quality of Service. This field is not provided in IPv4.

3. **Flow Label** – 20 bits are used for defining a sequence of packets that a source sends to the destination. This field is also not provided in IPv4.

4. **Payload Length** – These 16 bits hold the length of the extension headers including the transport-level PDU (Protocol Data Unit).
5. **Next Header** – These 8 bits are kept for identifying the type of the next header.

6. **Hop Limit** – 8 bits for the limited number of hops remaining for a packet. Each router decreases the number by one and when it reaches 0 it is being discarded

7. **Source address** – These 128 bits mention the address of the sender.

8. **Destination address** – These 128 bits mention the address of the receiving host.

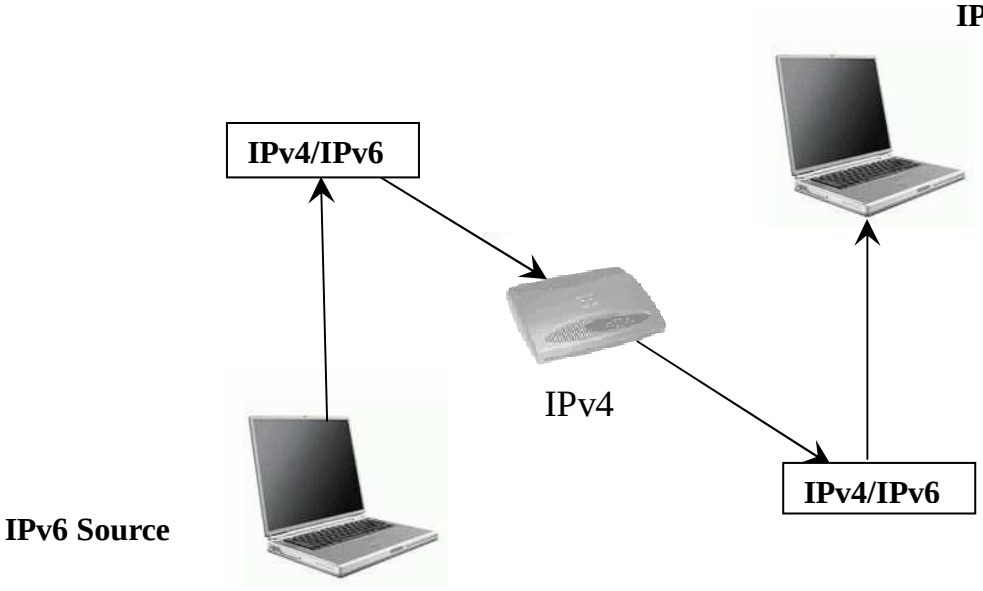

Fig 4: **Transition Process**

The transition from IPv4 to IPv6 is not trivial. There are millions of devices currently using IPv4 all over the world, maintaining compatibility between the older IP version and the newer one is crucial to a successful technology upgrade. There are certain mechanisms which implement transition features:

5.1 Dual Stack Configuration

Dual Nodes that implement both protocols at the same time are called IPv4/IPv6 nodes which read in each packet its protocol type (version 4 or version 6) and handle it accordingly. IPv6 packet is sent from the source to this dual node. Since the two versions function simultaneously, an IPv6 node easily creates and dispatch packets to IPv4. It extracts the lower 32 bits in the 128 bits address given by the IPv6 protocol.

5.2 Tunneling

Tunneling is a method for transmitting IPv6 packets using IPv4 infrastructure. An IPv4 header is attached i.e. encapsulated at the dual node and is sent to IPv4 router. The node on the other end of the tunnel removes the IPv4 header i.e. decapsulate and transmits the IPv6 packet to its destination.

5.3 Translation

A new network interface can obtain a unique address automatically when introduced to internet. It can be done in the following ways:

1. The Stateless mechanism – In this method the host creates his own address by amalgamating local information (in IEEE 802 the 48 bits MAC address) and information provided by the routers (e.g. the subnet address). In case a router doesn't exist, a host can create a link-local address that will be valid to the physical LAN to which it is connected.

2. The Stateful mechanism – In this method the hosts obtain the required information from a server (similar to DHCP).

Chapter 6 Conclusion

Summary
Over the years the internet users are constantly growing and it is expected that by year 2015 the users will be doubled to what they are now. Internet Protocol Version 4, the most widely accepted format to transmit data is reaching its end. The services it provides cannot accommodate address space for the exponentially increasing number of users, quality of service to the users, network access and bandwidth. The evolution of new applications E-commerce and Multimedia applications raised the necessity to transit to IPv6.The USA Government has asked for implementation of IPv6 all over USA by 2008.
IPv6 will be gradually deployed all over the world. The IPv6 working group is chartered to monitor the deployment and are responsible for research of newer inductions to IPv6. Already protocols supporting IPv6 are being developed for routers, firewalls etc. Collectively we can say that it is the genesis of a new revolution in the internet.

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